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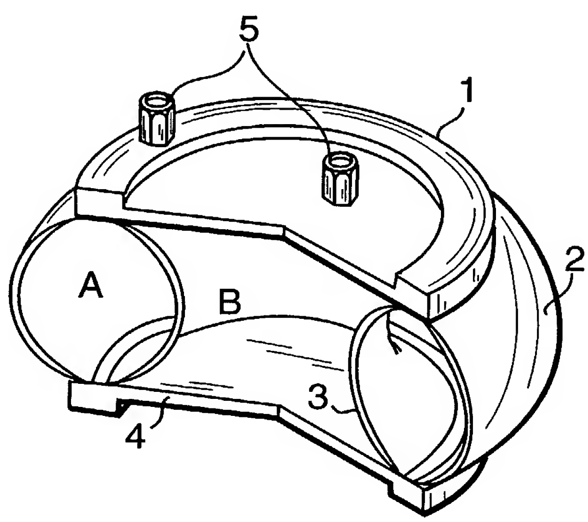
(54) Title: A DOUBLE-ACTING FLUID-DEFORMABLE ACTUATOR



(57) Abstract: The subject of the present patent is a fluid-deformable actuator which is able to exert a tensile force and a force of thrust. The actuator is built with two membranes (2,3) having an axisymmetrical geometry which, being constrained to two end pieces (1, 4) , delimit two coaxial chambers (A) and (B). The end pieces enable supply of the two chambers with fluid, as well as anchorage of the actuator to the structure to be moved. The membranes are made in such a way as to enable ample deformations in the circumferential direction and small deformations in the longitudinal direction. When the chamber (A) is supplied, a contraction of the actuator or exertion of a tensile force is obtained; when the chambers (A) and (B) are simultaneously supplied, an extension is obtained, i.e., a thrust.

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A DOUBLE-ACTING FLUID-DEFORMABLE ACTUATOR

The present invention relates to a double-acting fluid-deformable actuator which is able to exert both a tensile force and a thrust.

Recently, in the fluid actuator field, alongside the solutions of a traditional type, such as cylinders, there have been developed deformable actuators, where the very structure of the actuator is deformed as a result of a pressure, thus bringing about a contraction of the actuator itself and hence exertion of a tensile force. Such actuators, which are generically defined as being of the muscular type, present a number of advantages, such as low weight, high tensile force-weight ratio, absence of sliding parts, high efficiency, absence of any need for lubrication, possibility of working with low-cost and non-pollutant fluids (non-lubricated air, water), possibility of moving structures that are kinematically undefined, and possibility of working in extreme environments (absence of atmosphere, high surface-temperature gradients, etc.).

The aforesaid characteristics in particular

justify use of the said actuators for moving structures in the framework of robotic, biomechanical, and aerospace applications.

On the other hand, muscular actuators present the considerable disadvantage of being able to exert exclusively tensile forces and hence cannot be used in areas where double-acting actuation is required, unless two actuators are mounted according to the principle of antagonist muscles.

The actuator built according to the present invention adds to the advantages of a muscular actuator of a traditional type the possibility of exerting also forces of thrust and can therefore be used not only in automation systems, systems for handling and moving, and robotic structures, but also in active insulation of vibrations and in vehicle suspensions.

The item which forms the subject of the present invention, as claimed in claim 1, is made up of two coaxial deformable membranes of a cylindrical shape or of some other shape constrained at two end pieces so as to identify two coaxial chambers, an inner chamber and an outer chamber.

The deformable membranes present considerable deformability in the circumferential direction and

low deformability in the axial direction. This characteristic may be obtained, for example, using an elastomeric membrane that is stiffened longitudinally by fibres embedded in the matrix.

The end pieces enable separate supply of the two coaxial chambers, guarantee tightness of sealing of the two chambers, and enable anchorage of the actuator to the structure that is to be moved.

By supplying the outer chamber with pressurized fluid, both of the membranes are deformed in a circumferential direction but are not deformed axially, thus causing the end pieces to come closer to one another, i.e., exerting a tensile force. Instead, by supplying simultaneously both the outer chamber and the inner chamber, the action of the pressurized fluid on the end pieces brings about extension of the actuator, i.e., exertion of a force of thrust.

The actuator forming the subject of the present invention is able to exert both a tensile force and a force of thrust.

The aforesaid actuator operates only by means of deformation of the structure and hence without any relative sliding of parts belonging to it. As a result, under normal conditions any phenomena of

sliding friction and corresponding wear are thus absent, and any danger of leakage of the working fluid is ruled out.

The actuator forming the subject of the present invention has an intrinsic deformability, which enables its use in the area of bi-directional actuation of cinematically undefined structures.

The said actuator is able to operate with different working fluids both liquids and gases. In particular, it is able to work with low-cost fluids, such as water or non-lubricated air.

If the actuator is supplied with compressible fluid, it presents an intrinsic compliance, which justifies its use in the framework of vehicle suspensions and active insulation of vibrations.

The aforesaid actuator is able to work in hostile environments, in the presence of electromagnetic fields, in the absence of atmosphere, and in the presence of marked temperature gradients, and is thus suited for aerospace applications.

On account of its ease of sterilization and the absence of leakages, the actuator can be used in the biomedical field for moving structures in clean rooms.

Advantageously, actuators of the type described

in the present patent can be built with different ratios between the distance of the end pieces and the diameters of the deformable chambers, to obtain actuators with different mechanical characteristics, which can be adapted to the needs of the particular application.

Advantageously, the end pieces of the actuator can be built in such a way as to enable connection of two or more double-acting fluid-deformable actuators in series and thus obtain an actuator with a greater stroke than that of the single actuator.

Advantageously, it is possible to obtain the same effect by reducing the axial dimensions of the actuator, simply by interposing, in appropriate definite axial positions, appropriate rings for radial containment both of the inner membrane and of the outer membrane.

Advantageously, it is possible to achieve a saving of working fluid at each cycle, by filling the space of the inner chamber not occupied by the membrane with an appropriate inert material.

Advantageously, it is possible to achieve a saving of working fluid at each cycle, by supplying the actuator in the thrust phase, connecting the outer chamber directly to the inner chamber.

Further advantages and characteristics of the present invention will emerge clearly from the ensuing detailed description, which is made with reference to the attached drawings, provided purely by way of non-limiting example and in which:

- Figure 1 represents the assembly drawing of the actuator;

- Figure 2 represents possible sizes and proportions of the actuator;

- Figure 3 represents a possible assembly in series of the actuators;

- Figure 4 represents a compact actuator with large working stroke;

- Figure 5 represents a possible constructional solution of the actuator;

- Figure 6 represents a possible solution for reducing the consumption of the working fluid; and

- Figure 7 represents a diagram of supply with energy saving.

Figure 1 is the assembly drawing of the actuator. The end pieces 1 and 4 are constrained to the axisymmetrical deformable membranes 2 and 3, which are axially stiffened by means of fibres. In this way, two chambers are identified: the outer chamber A and the inner chamber B. By supplying fluid

to the outer chamber A, by means of one of the two connectors 5, the actuator contracts, as represented in Figure 1, i.e., it exerts a tensile force. Instead, when the inner chamber B is supplied, the actuator extends, i.e., it exerts a force of thrust.

Figure 2 represents two different possible geometries of the actuator. Actuators with a high ratio between length of the membranes and radius of the end pieces present a high capacity for exerting tensile force. Actuators with a low ratio between length of the membranes and radius of the end pieces present a high capacity for exerting thrust. Given the same ratio between length of the membranes and radius of the actuator end pieces, actuators of larger size operate in wider ranges of force given the same pressure of the working fluid.

Figure 3 illustrates an assembly of the actuators in series, which can be obtained by means of appropriate solutions in construction of the end pieces. The actuator thus built has a high working stroke, whilst the same performance of the individual actuator in terms of force is maintained.

Figure 4 illustrates an alternative solution of actuator with large working stroke. Appropriate circumferential stiffening rings, both internal ones

and external ones, set along an actuator with high ratio between length of the membranes and radius of the end pieces enable an actuator with large working stroke and small overall dimensions to be obtained.

Figure 5 illustrates a possible constructional solution of the actuator according to the invention. In particular, the modalities of constraint of the end pieces to the membranes may be noted. The inner membrane is found to be closed between two conical surfaces 11 and 12, which are fastened by means of screws 13. The outer membrane 2 is closed on the end pieces 1 and 4 by means of adjustable clamps 14. Supply of the outer chamber A is performed by means of the connector 5 and annular supply chamber 6, which is insulated from the outside environment by two O-rings 7. Supply of the inner chamber B is obtained by means of the connector 8.

Figure 6 presents a schematic cross section of the actuator according to the invention, which highlights the possibility of accommodating within the inner chamber B a space for filling 10 such as not to interfere with the end pieces and the membranes 2 and 3 and which is capable of reducing consumption of working fluid at each filling cycle.

Finally, Figure 7 presents a diagram of the

possible circuit for supplying the actuator, which enables both supply of either of the working strokes (standard operating mode) and operation with low fluid consumption (operation with recovery of energy). According to the standard operating mode, with the valves positioned in resting conditions, the outer chamber A of the actuator is supplied, the chamber B is discharged, and the actuator contracts. When the valve V1 is switched, the inner chamber B of the actuator is also supplied, and the actuator extends. In the operating mode with recovery of energy, when the valve V1 is, instead, kept in its normal position and the valve V2 is switched, the outer chamber A is connected to the inner chamber B, and the actuator, from the contracted position, lengthens with recovery of energy. This operating mode is possible only with the use of compressible fluids. In fact, the fluid initially contained in the chamber A expands in the spaces provided by chamber A and chamber B during the thrust stroke. The external work is thus obtained by recovering energy from the pressurized fluid by means of its expansion.

C L A I M S

1. A double-acting fluid-deformable actuator made up of two axisymmetrical membranes (2,3) capable of undergoing ample deformation in the circumferential direction and with small capacity for deformation in the longitudinal direction, the two membranes being constrained to two end pieces (1,4) having the function of connecting the actuator to the structure or mechanism that is to be moved and being such as to identify two coaxial chambers (A,B) of supply.

2. The actuator according to Claim 1, characterized in that, even with different geometrical solutions, by supplying one chamber (A or B), there is an increase in volume with a corresponding contraction of the actuator, and by supplying the other chamber (B or A) or both of the chambers (A,B) there is an increase in volume with corresponding extension of the actuator.

3. The actuator according to Claim 1 and Claim 2, characterized in that the constraint of the membranes (2,3) to the end pieces (1,4) is obtained by means of conical coupling (11,12) and/or by means of adjustable clamps (14).

4. The actuator according to Claims 1 to 3,

characterized in that the elements(5,8) of connection of the end pieces also function as supply paths for the chambers (A,B) since they have longitudinal holes.

5. The actuator according to Claims 1 to 3, characterized in that it has a deformable chamber of high slenderness, on the outer surface of which there are set, at predefined distances, stiffening rings such as to prevent radial displacement of the walls of the chamber and of the inextensible fibres in the positions where they are arranged.

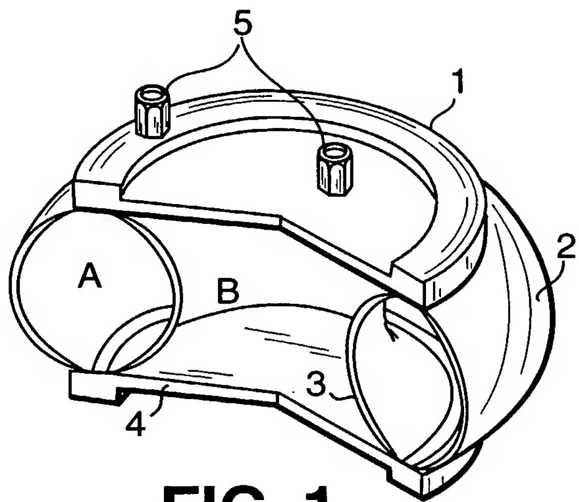

FIG. 1

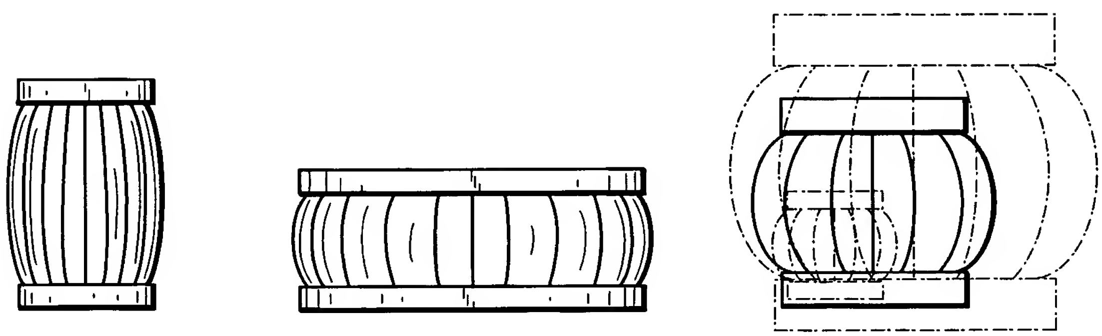

FIG. 2

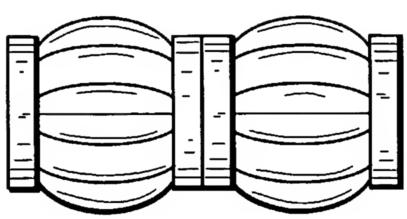

FIG. 3

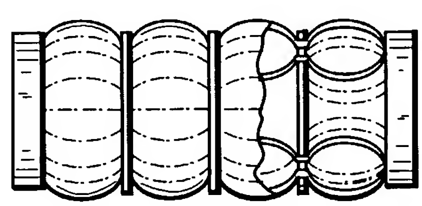

FIG. 4

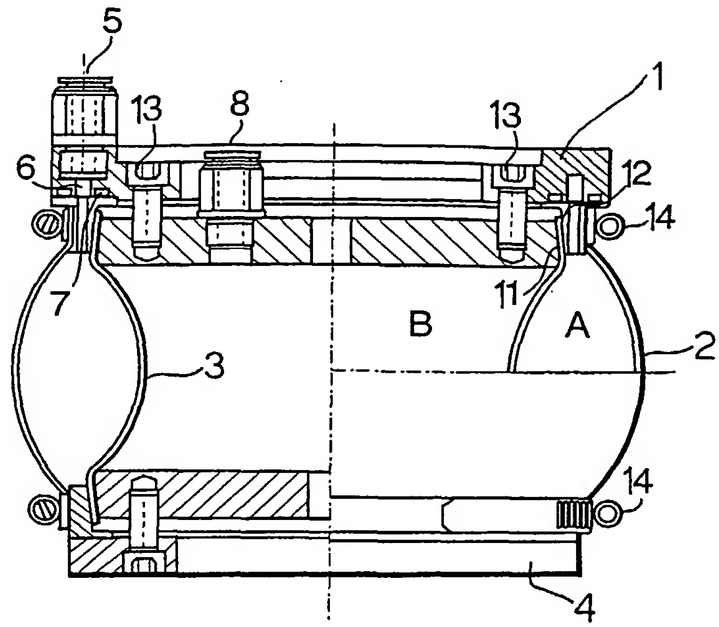

FIG. 5

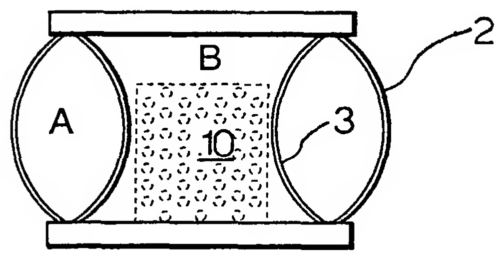

FIG. 6

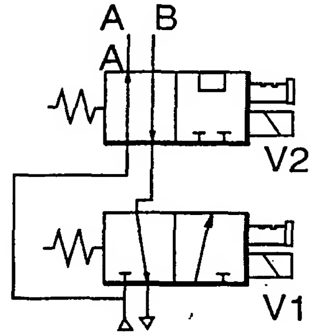

FIG. 7

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 02/11633

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F15B15/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F15B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y		3-5
X	FR 2 647 527 A (BARRAS PROVENCE) 30 November 1990 (1990-11-30) page 5, line 29 -page 8, line 36; figures 2-5	1,2
A	GB 2 328 981 A (GREENHILL RICHARD MARTIN) 10 March 1999 (1999-03-10) page 5, paragraph 1 -page 6, paragraph 2; figure 4	1
Y		3

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
10 January 2003	28/01/2003

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 02/11633

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2 844 126 A (GAYLORD RICHARD H) 22 July 1958 (1958-07-22) column 2, line 9-18; figure 1	1,3
A	US 5 067 390 A (NEGISHI KOICHI) 26 November 1991 (1991-11-26) column 3, line 36-60; figure 2	1-3
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A	US 5 185 932 A (CAINES R SCOTT) 16 February 1993 (1993-02-16) column 28, line 28-31; figure 8	1-3
Y		5

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
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